

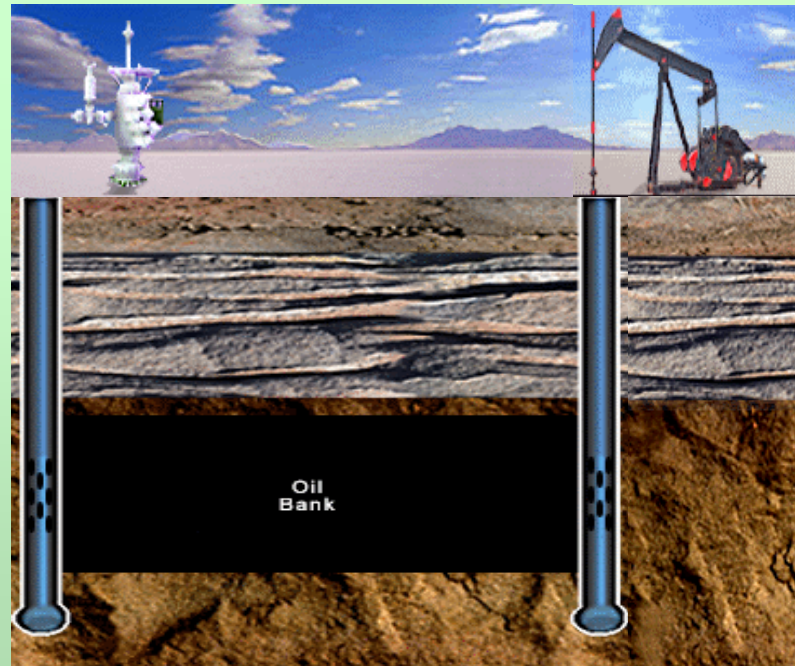


IEA Weyburn CO₂ Monitoring and Storage Project Weyburn, Saskatchewan, Canada

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Project Mission

To assess the technical and economic feasibility of geological storage of CO₂ in oil reservoirs and develop implementation guidelines for such projects.

Implicit in the assessment is the identification of the risks associated with this method of CO₂ storage, particularly long-term risks of CO₂ leakage.





The US DOE Perspective

- We must demonstrate the economic benefits of CO₂ sequestration to ensure the option is viable and will encourage a price for CO₂
- The US has over 60 world-class EOR projects and is the world leader in this technology area
- The CO₂ being used in this EOR project comes from the US and helps improve the economics of the Dakota Gasification Plant and the associated lignite industry in North Dakota
- Technology development in this area is key to National Energy Security
- The Weyburn field is only using about 40% of the pipeline capacity; there are US producers in the Williston basin waiting to see the technology proven by EnCana
- A large portion of the Williston basin in the US (2/3)
- The value of international collaboration: the total is greater than the sum of parts



The NRCan Perspective

- Understanding CO₂ capture and geological storage is an important aspect of maintaining the fossil energy option in a carbon-constrained world.
- This project will help ensure public acceptability of this important climate change option
- The results of this project will form part of the justification made by policy makers to exercise this climate change option
- A unique opportunity to monitor CO₂ geological storage from cradle to grave in a single project
- This project has the potential to represent the sustainable development goal: economically viable, environmentally responsible and socially acceptable.
- National and international public and private sector interests converge, giving us a rare opportunity to accomplish normally divergent goals.

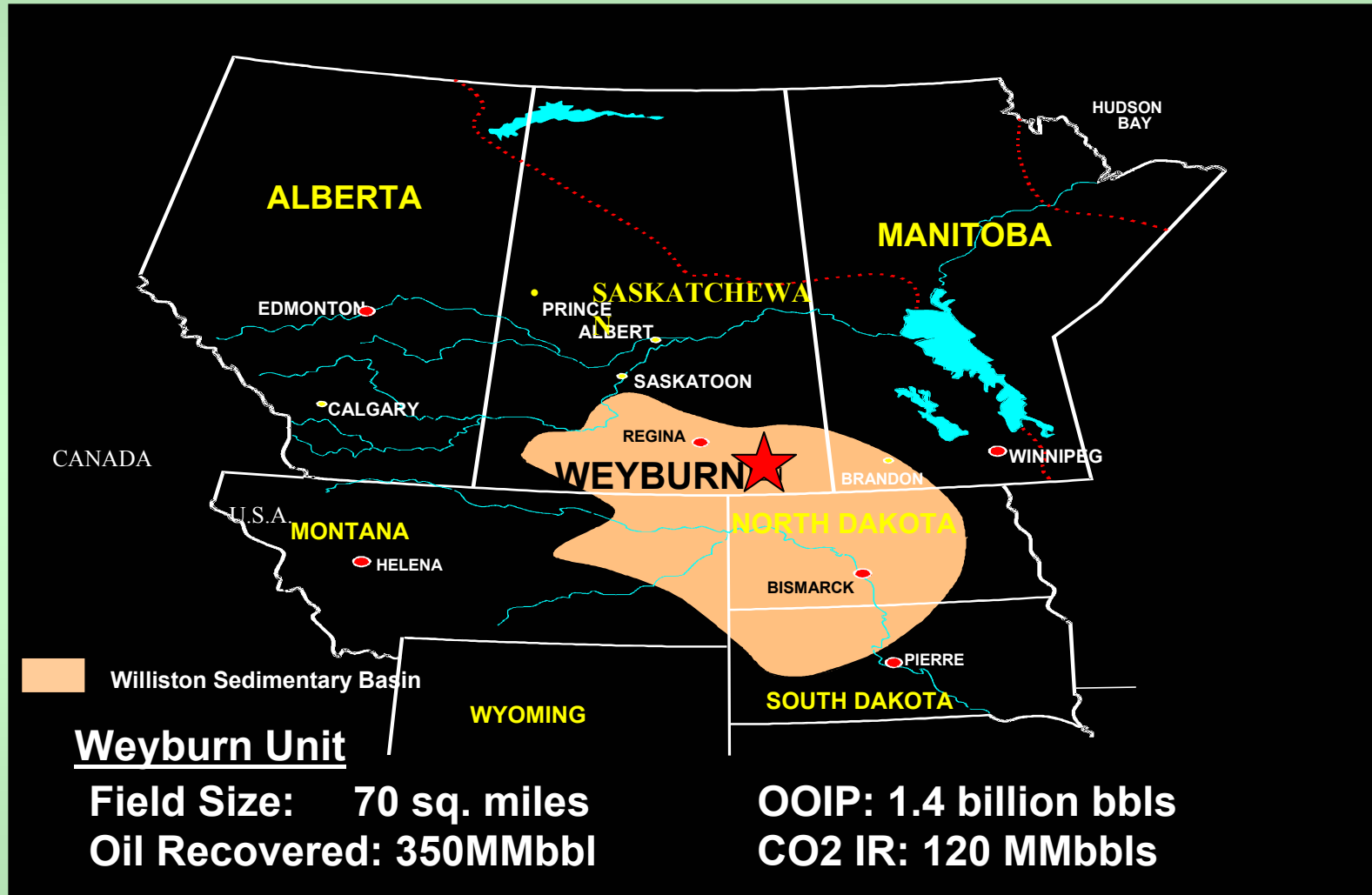


Project Objectives

- Define the geoscience framework of the storage medium (the “geosphere”)
- Refine CO₂ movement predictions and verification techniques
- Identify the short- and long-term risks of CO₂ migration and leakage
- Improve storage capacity through improved reservoir conformance (CO₂ mobility control, various operating strategies)
- Define the economic limits of CO₂ geological storage



Weyburn Field



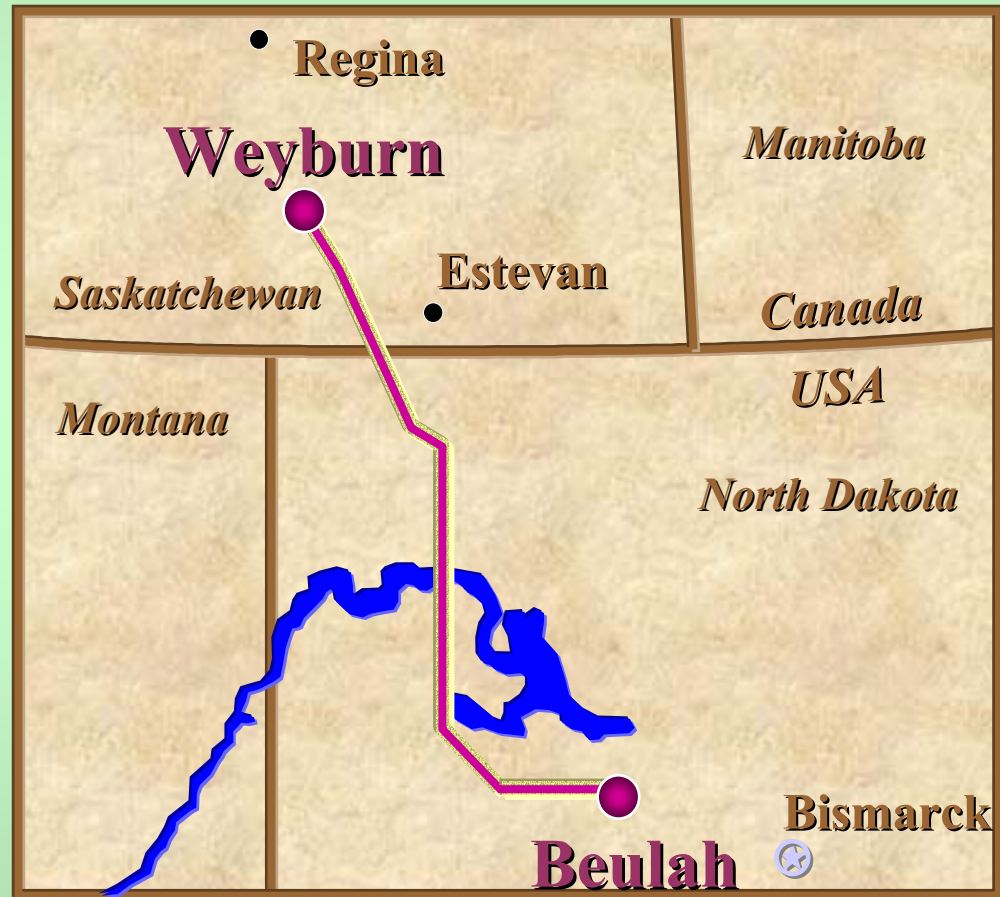


Why Was The Weyburn Unit Selected?

- World-class CO₂-enhanced oil recovery (EOR) project (CDN \$1.5 billion)
- Easily accessible site
- Substantial historical data base
- Extensively drilled with accurate records
- Pre-injection baseline data could be gathered
- Supportive industrial partner (EnCana Corporation)

The Source of CO₂

- Dakota Gasification Company
- 250 mmscfd CO₂ by-product of coal gasification
- 95 mmscfd contracted and injected at Weyburn
- CO₂ purity 95%





Project Sponsors

\$14 Million in cash

Governments:

- Saskatchewan Industry & Resources (SIR)
- Natural Resources Canada (NRCan)
- Alberta Energy Research Institute (AERI)
- United States Department of Energy (USDOE)
- European Community (EU)

Industry:

- EnCana Corporation
- SaskPower
- Nexen Canada
- TotalFinaElf
- ChevronTexaco
- BP
- Dakota Gasification Co.
- TransAlta Utilities Corp.
- Engineering Advancement Association of Japan



Research Providers

\$14 Million in kind

Canada

- EnCana Corporation
- Saskatchewan Industry & Resources
- Saskatchewan Research Council
- University of Alberta
- University of Calgary
- University of Saskatchewan
- University of Regina
- J.D. Mollard and Associates Ltd.
- Alberta Research Council
- Geological Survey of Canada (NRCan)
- Hampson Russell-Veritas
- Rakhit Petroleum Consulting
- Ecomatters Inc.
- Canadian Energy Research Institute

United States

- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Colorado School of Mines
- Monitor Scientific LLC
- North Dakota Geological Survey

Europe

- British Geological Survey (UK)
- BRGM (France)
- GEUS (Denmark)
- ING (Italy)
- Quintessa Ltd. (UK)



Project Communication

- Integration of all project elements is essential for determining long-term integrity of CO₂ storage
- There are over 20 research providers and 15 project sponsors making communication and IP management a big challenge
- eRoom has enabled a huge database of technical and management information to be shared in confidence by all project participants
- Use of eRoom early in the project ensured use of common tools by project participants, ensuring information compatibility
- eRoom information includes technical management committee minutes, project control documents, quarterly and annual reports, presentations and publications, etc.
- eRoom has the capability to allow for on-line virtual meetings



Project Scope – Principal Tasks

- Field Performance Monitoring
- Geoscience Framework (Geosphere)
- Geochemical Monitoring & Modeling
- Caprock and Wellbore Integrity
- Seismic Tracking of CO₂
- Numerical Simulation of CO₂ Movement
- Long-Term CO₂ Fate Assessment
- CO₂ Storage Economic Model

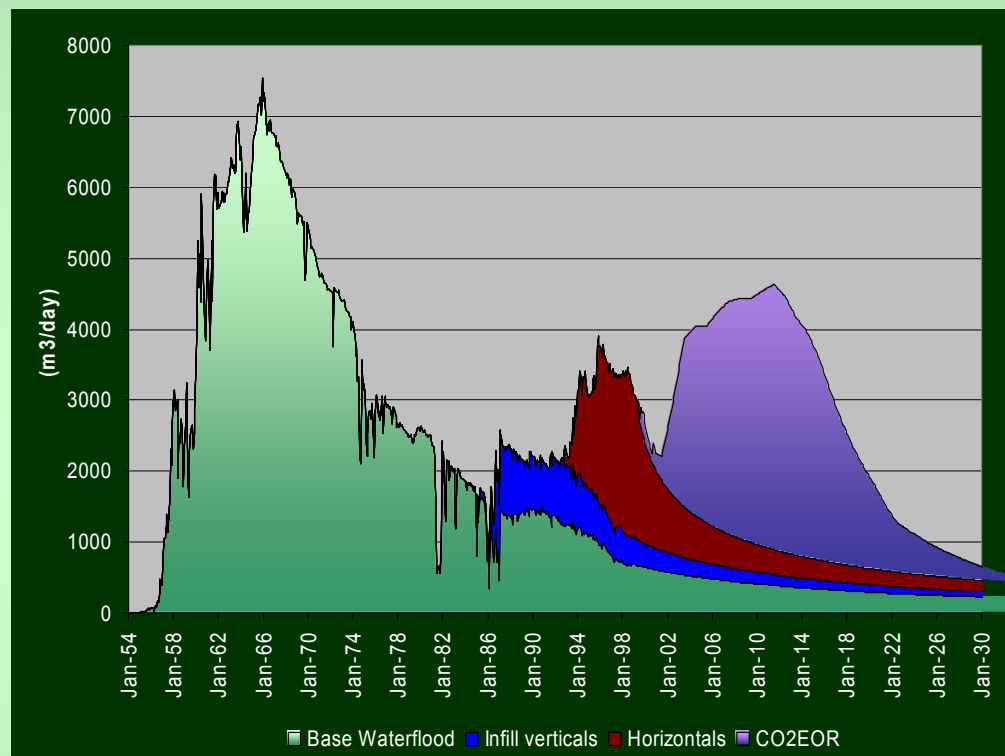
Note: Principal tasks are subdivided into 31 sub-tasks, each managed by a team of research providers.

Operations

Update

(from Sept. 2000 – Dec. 2002)

- CO₂ injection into Phase 1A started Sept. 2000
- CO₂-EOR flood to 2025
- 20 M tons of CO₂ stored over 25 yrs
- Commercial project is rolling out beyond the Phase 1A monitoring project area
- Current CO₂ purchase: 3700 t/day
- 29% injected gas recycle
- 2.71 M tons injected to the end of Dec. 2002 (1.7 tons stored)
- 4.14 M tons injected to the end of Dec. 2003 (2.7 tons stored)
- Current incremental production: 4500 bbl/day (~ 25% total)



Monitoring CO₂ Movement



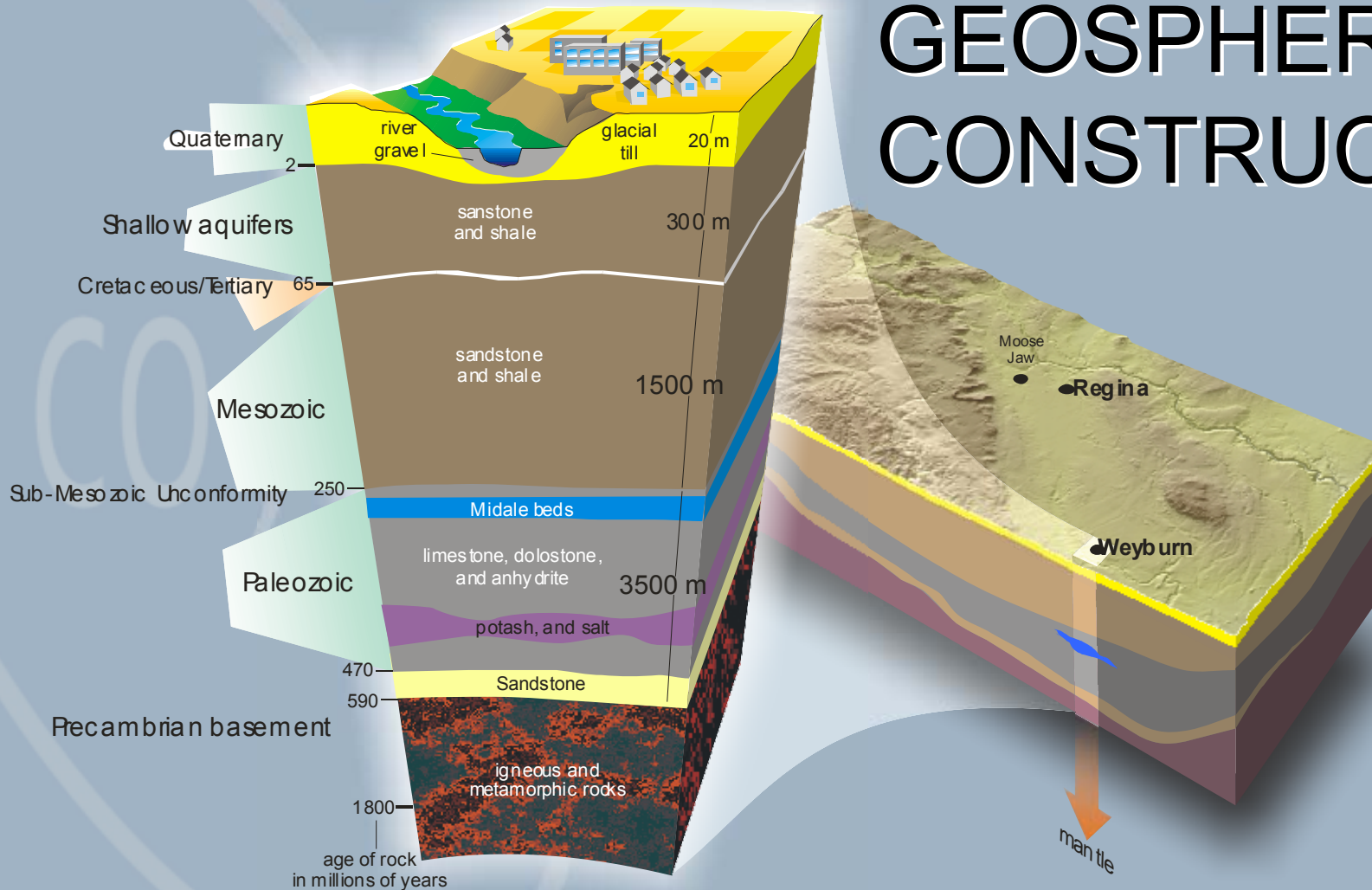
Techniques

- 4D, 3C surface seismic
- 4D, 9C surface seismic
- 3D, 3C vertical seismic profile (VSP)
- Cross-well seismic (H and V wells)
- Passive micro-seismic
- Geochemical sampling analysis
- Tracer injection monitoring
- Conventional produced fluid analysis

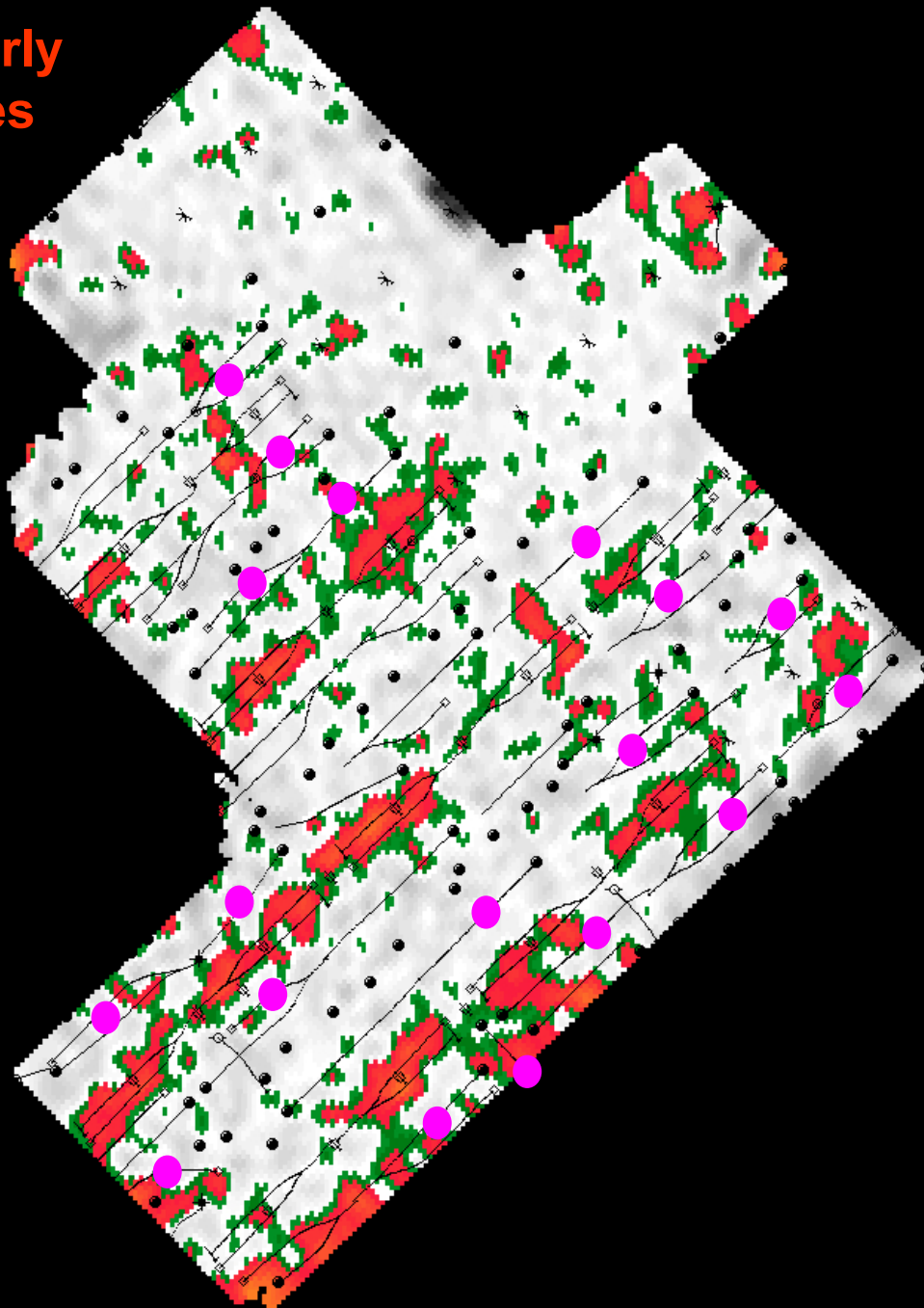


Project Results

GEOSPHERE CONSTRUCTION



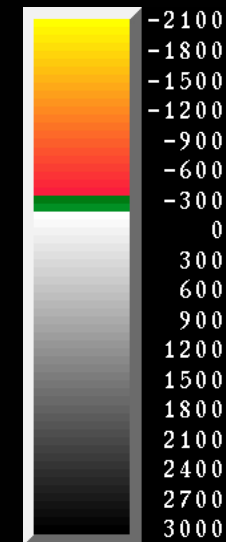
Midale Marly Amplitudes (3 x 3 smoother)



Seismic Detection of Weyburn Field CO₂ Miscible Flood

EnCana et al.
4-D P-Wave Data
(Bin Size 40 x 40 m)

Amp Scale



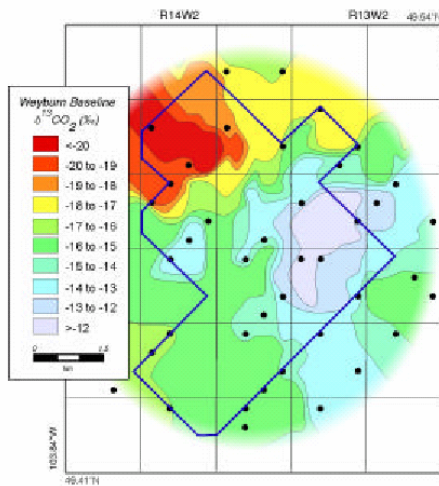
CO₂
Related
Anomalies

● Response well

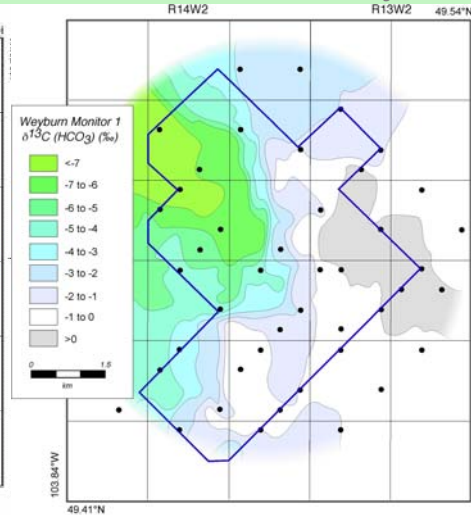
Fluids in the Reservoir

$\delta^{13}\text{C}(\text{HCO}_3)$ (aqueous)

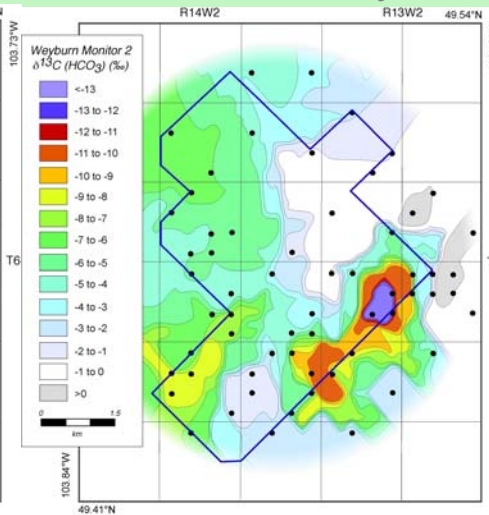
Baseline Survey



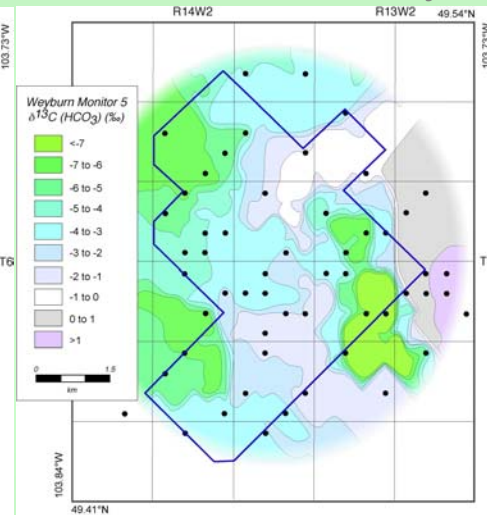
6-Month Survey



1-Year Survey



22-Month Survey



Injected CO_2 into solution

pH decreased



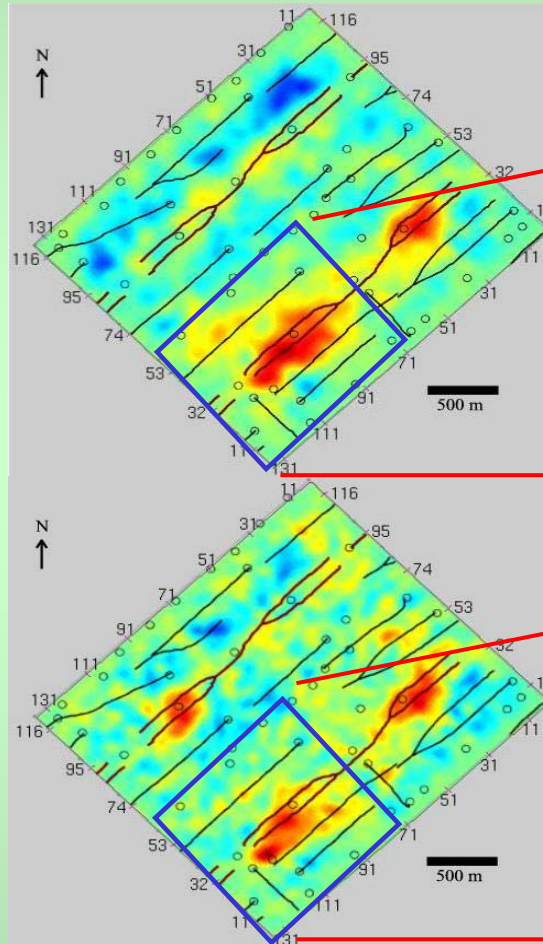
Carbonate Mineral dissolution

pH increased



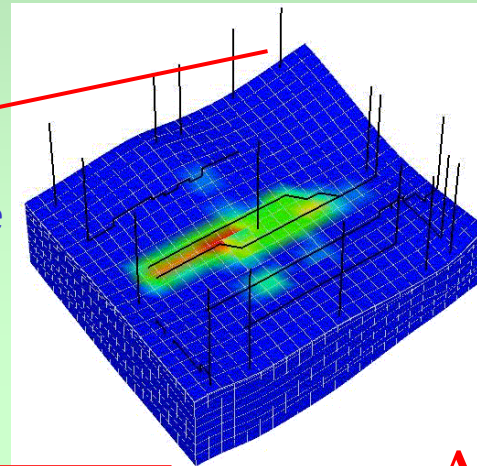
Integrated Progress

Task 4: Monitoring CO₂ Movements

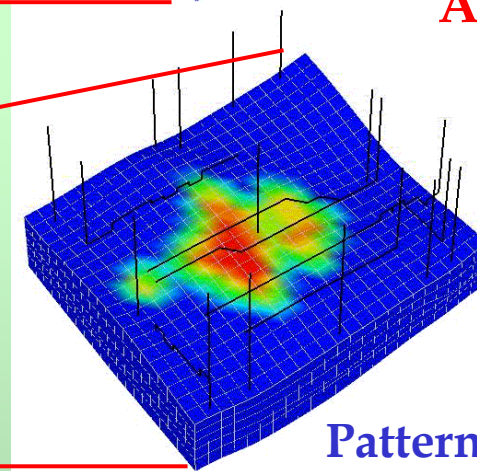


Marly Zone

Vuggy Zone



After 1 year



Pattern 1 (P1612614)

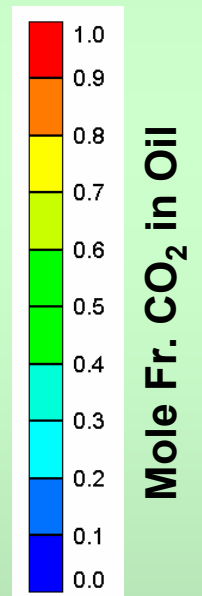
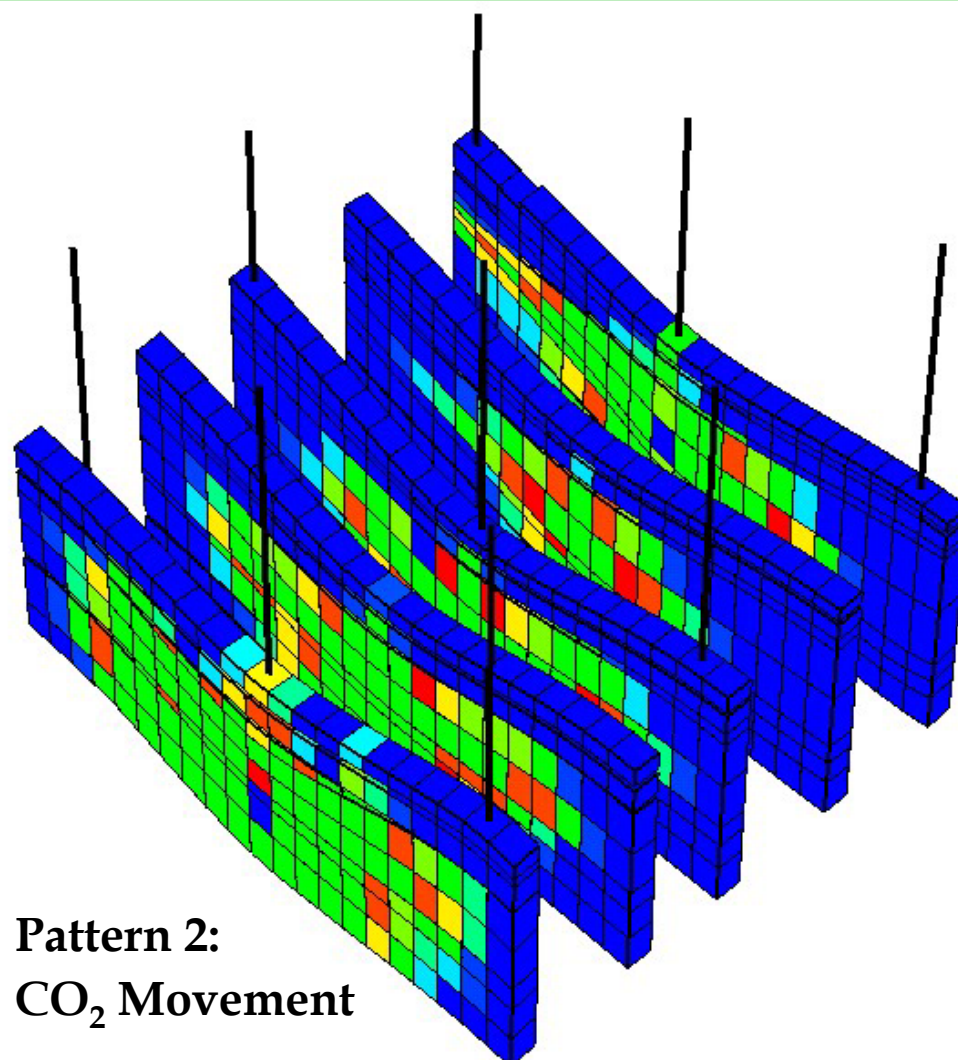
CSM 4D 9C Surface Seismic
(P-Impedance Changes)
EnCana

Numerical Simulation by ARC



Reservoir Modeling

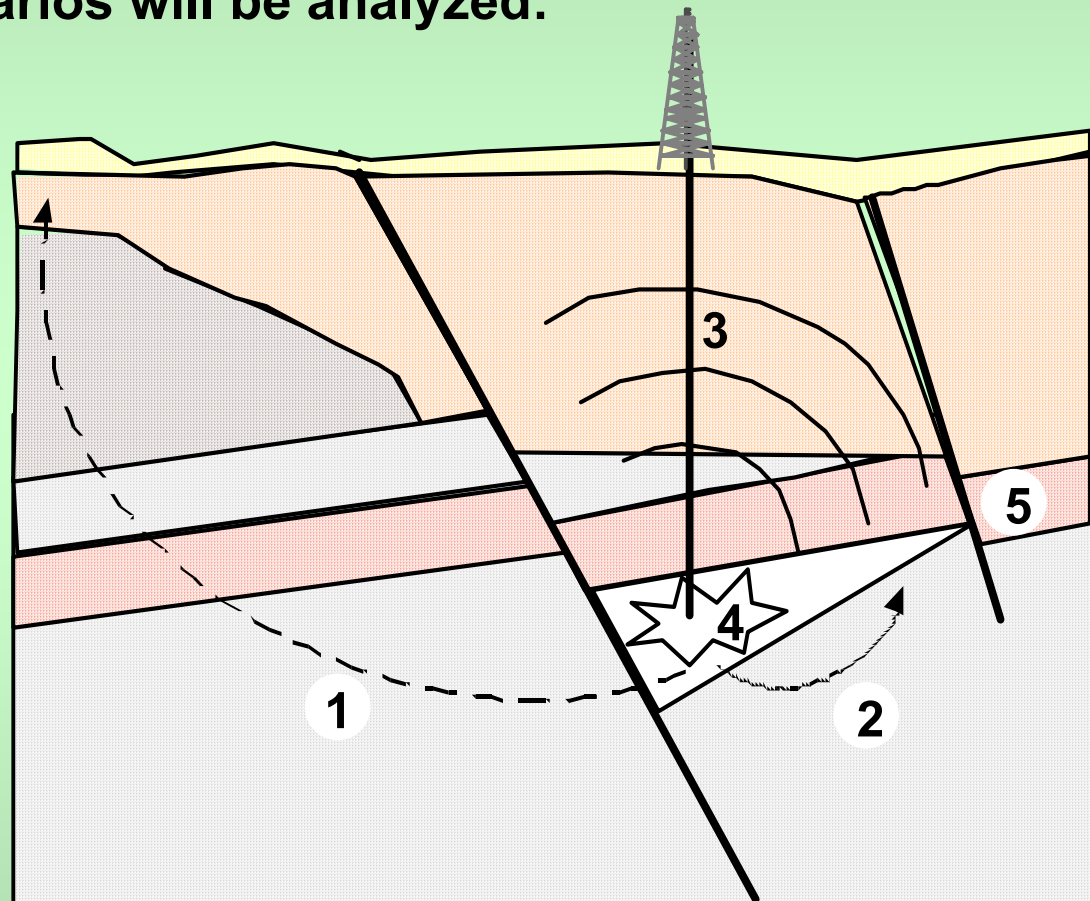
10 yrs



Risk Assessment (RA) of CO₂ Sequestration

A number of escape scenarios will be analyzed:

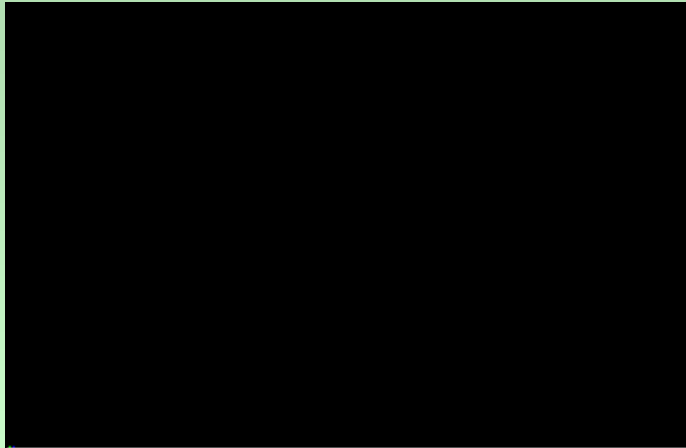
1. Rapid “short-circuit” release
2. Potential long-term release
3. Induced seismic event
4. Disruption of host rock
5. Release to aquifer



Conclusions

- Great cooperation and support among sponsors and research providers
- Technically important for credibility of carbon sequestration
- Developing a suite of leading-edge monitoring and verification technologies
- Applicable to many sites around the world (not just EOR)
- Very encouraging results midway through project; major challenges facing the project:
 1. Integration of all elements of project
 2. Meeting deliverables on time
 3. Final project documentation and refereed publications (IPCC report)
 4. Many more questions need to be answered, which can be achieved by maximizing interpretation of data
- The commercial flood will continue for another 20+ years. There is a unique opportunity to monitor the flood during the commercial operation and monitor CO₂ storage from “cradle to grave”. Should we initiate a Phase II project?





No Picture

eds_cathering_low.MPG